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SAPPLT DOCUMENTATION (VAX-11/750 VERSION) - AN INTERFACE PROGRAM FOR THE GENERAL PURPOSE PLOTTING PROGRAM MRLPLT

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AUGUST 1985

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MICROMEDIA
JAN 21 1986

MINERAL RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT MRP/MRL 85-86 (TR)

36pp

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by

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ABSTRACT

SAPPLT is one of the component programs contained in the SAP2D system. It is an interface program for the general purpose plotting routine MRLPLT. Together with MRLPLT it serves as the post- processor for the finite element program *SAP2D*. The basic function of SAPPLT is to convert SAP2D output data (*i.e.*, stresses and displacements) into a set of input files acceptable to MRLPLT; MRLPLT then provides graphic representation of finite element analysis data.

This report documents SAPPLT. In particular, the file used, the program capabilities, and input instructions are described. In addition, a command procedure for VAX/VMS system is provided.

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DOCUMENTATION SUR LE SAPPLT (VAX-11/750) PROGRAM D'INTERFACE POUR LE PROGRAMME DE ROUTINES POLYVALENTES DE TRAÇAGE MRLPLT

par

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RÉSUMÉ

Le SAPPLT est un des programmes faisant du système SAP2D. Le SAPPLT est un programme d'interface pour le programme de routines polyvalentes de traçage MRLPLT. Ainsi avec le MRLPLT, il sert de postprocesseur au programme d'analyse par éléments finis SAP2D. La fonction de base du SAPPLT est de convertir les résultats du SAP2D (c.-à-d. la tension et les déplacements) pour produire un fichier d'entrée qui sera acceptable au programme MRLPLT; le MRLPLT fournira alors une représentation graphique des résultats d'analyses des éléments finis.

Le présent rapport documente le SAPPLT. Notmment les fichiers utilisés, les possibilités du programme et les directives d'entrée requises y sont décrits. En outre, une méthode de commande pour le système VAX/VMS est fournie.

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1.0 INTRODUCTION

SAPPLT is an interface program for the general purpose plotting routine MRLPLT [1,2]*. It converts SAP2D [3,4] output data (stresses and displacements, *etc.*,) into a set of input files acceptable to MRLPLT. MRLPLT provides graphical representation of the stress and displacement results of two-dimensional finite element stress analysis. Three types of plots can be generated by MRLPLT: These are:

1) **vectors**;

2) **tensors**; and

3) **point contours.**

The **vector** plot was designed to display nodal displacements or any other similar data. The **tensor** plot produces a representation of two principal values of second-order tensors, such as the stress trajectories of the principal stresses for plane structures. The **point contour** plot can be used for any quantity dependent on two variables, X and Y; it assigns a symbol to each data point according to the range of the data in relation to a set of contour intervals.

To evaluate the stability of a structure, using the stresses obtained from a finite element analysis, the Mohr-Coulomb failure criterion and Drucker-Prager yield criterion are incorporated into the SAPPLT program. The stability or instability at a point within a structure is represented by a symbol which is referred to as the local factor of safety, and, these safety factors can be plotted in a **point contour** form.

The program SAPPLT was originally written for a CDC 6000 computer. Recently, it was modified in accordance with the ASCII 77 Fortran standard, and is now operational on a VAX-11/750 mini-computer under the VMS operating system. The plotting devices available for the general purpose program MRLPLT are currently a Tektronix 4663 plotter and a 4014 compatible graphic display terminal [2]. The input requirements of MRLPLT, its data structures and plotting capabilities have been described in detail in Reference [2]. It is recommended that the reader should also refer to the above reference if this interface program SAPPLT is to be used. This report documents SAPPLT. In particular, the file used, the program capabilities and plotting options, and input data instructions are described. In addition, a command procedure for the VAX VMS system is provided.

---

* Number(s) refers to cited references.

2.0 FILE USAGE

Five logical files are associated with the SAPPLT program. These are described as follows:

Logical File Name	Description
SAPOUT	Contains the output file of a finite element stress analysis using the program SAP2D [3,4].
PLTIN	Contains the data to be plotted by MRLPLT. This file will be generated by the program SAPPLT.
PLTCMD	Contains the MRLPLT input commands. This file will be generated by the program SAPPLT.
FOR005	The SAPPLT input commands file (refer to Section 3.0).
FOR006	The SAPPLT print-output file

3.0 INPUT INSTRUCTIONS

3.1 GENERAL

As mentioned earlier, SAPPLT is an interface program for the plotting routine MRLPLT [2]. Prior to executing the program MRLPLT, three input files need to be prepared. They are:

a) MRLPLT plotting data file – PLTIN;
b) MRLPLT input command file – PLTCMD; and
c) MRLPLT boundary file – PLTBND.

The first two files will be generated by the program SAPPLT, using the SAP2D output file SAPOUT, plus additional information from the input command file (FOR005). The third file, PLTBND, can either be entered within the input stream of SAPPLT, or generated by the BNDGEN program. The use of BNDGEN is very simple, and the only input required is SAPOUT. Further details concerning the use of BNDGEN are given in Section 4.

The SAPPLT input command file, *i.e.*, the input required by SAPPLT is divided into four groups, namely:

a) the plot initial commands;
b) the plot type command;
c) the plot parameter commands; and
e) the boundary data, if required.

3.2 DETAILED INSTRUCTIONS

3.2.1 The Plot Initial Commands:

Card No. 1:

FORMAT (4I5, 1X, A4, 2X, A3, 4X, A1, F10.0)

READ ,NPLOT, NBSET, ID, NLINES, KEYWRD, DEV, PAGCHG, BWIDTH

NPLOT – Number of plots to be created.

NBSET – The number of boundary files residing on 'PLTBND'.
If NBSET > 0, NBSET boundary files already exist on file 'PLTBND' (possibly created by 'BNDGEN', and refer to Section 4.1). If NBSET < 0, |IABS| card boundary files are to be transferred to PLTBND. The format is (1X, 2E15.7, I5). See Section 3.2.4 for a description.
If NBSET = 0, A total of NBOUND (specified on Card No. 4) boundary point cards should be input for each plot. The format is (1X, 2E15.7, I5). See Section 3.2.3(h) for a description.

ID – If nonzero then input a $IDENT card (Card No.2).

NLINES – If NLINES > 0, it is the total number of cards to be input for the plot title (Card No.3).

KEYWRD – 4 character data location indicator:
if KEYWRD =' ', ie., 4 blanks, the plot data will be generated by SAPPLT and stored on PLTIN;
if KEYWRD ='CARD', plot data is to be input from cards.

DEV – 3 character string that identifies the plot device;
available devices are:
PA2 - the Tektronix 4663 with page size 'drafting' A2.
PA3 - the Tektronix 4663 with page size 'drafting' A3.
PA4 - the Tektronix 4663 with page size 'drafting' A4.
TKT - the Tektronix 4014 terminal.
CAL - the Calcomp plotter (this option is not tested).
The default value of DEV is 'PA3'.

PAGCHG – 1 character string that determines how plot page changes are to take place. Possibilities are:
U - user manually changes the page.
A - page changes are automatically made by the device.

BWIDTH – The width of plot border in inches. The default values are 0.0 and 1.0, respectively, for a contour plot and vector or tensor plot.

Card No.1 (continued)

Note:

(a) When DEV is the 4663 plotter, then:
PAGCHG should be set to 'U' if media form is set to sheet.
PAGCHG should be set to 'A' if media form is set to roll.

(b) When DEV is 'PA2', 'PA3', or 'PA3', then:
The initial aspect ratio parameter should be set to 4X:3Y.
The initial page format parameter should be set to drafting.

(c) The default page sizes (XPAGIN, YPAGIN) are:
PA2 - 20.65, 15.75
PA3 - 14.30, 10.91
PA4 - 9.81, 7.48
TKP - 14.30 10.91
TKT - 14.28, 10.89
CAL - 40.00, 29.00

(d) When DEV is the Tektronix 4014 terminal, then:
MRLPLT must be executed interactively when PAGCHG = 'U'. In this case the user must input a carrige return (CR) at the end of each plot. When executing interactively on the 4014 terminal, remenber that FOR006 (the print output) must be assigned to a file or the null device, otherwise, the print output will appear with the plot.
If PAGCHG = 'A', then the plots will appear so rapidly that the user will see only the last plot page.

(e) The DEV = 'CAL' option is not test.

Card No. 2:

FORMAT (A10, 10A4)

READ ,Label, NAME

Label – $IDENT

NAME – A 40 character string for your name and address identification.

Card No. 3:

FORMAT (20A4)

If NLINES specified on Card No. 1, is greater than zero, then input 'NLINES' cards for plot title or identification. A maximum of 5 cards is permitted.

3.2.2 The Plot Type Command

Card No. 4:

FORMAT (3X, A2, I5, F5.0, 5I5)

READ ,KPLOT, NFDATA, SQUARE, ISLECT, NDFMT, NBOUND, NBFMT, NOLABL

KPLOT – 2 character string determines the type of plot to be executed. The type of plots available are:

DD – Displacements or differential displacements between two sub-problems (vector plot).

ST – Stress trajectory plot (tensor plot)

MJ – Major principal stresses, *i.e.*, the smaller compressive stress if the sign convention of compression negative is adopted (point contour plot).

MN – Minor principal stresses, *i.e.*, the larger compressive stress if both MJ and MN are compressive (point contour plot).

SF – Yield factor or local factor of safety (point contour plot, please refer to Appendix C for details).

SC – Shear stress on a specified plane (point contour plot).

NC – Normal stress on a specified plane (point contour plot).

Note: If the shear stresses or normal stresses acting on a specified plane is required for plotting, the user should modify a user-supplied function subprogram, THETAF, in the SAPPLT program.

Card No. 4 (continued)

NFDATA – File number of data to be used to create 'PLTIN' file.
If NFDATA > 0, a file is added to 'PLTIN'. In this case, NFDATA should be equal to the number of files previously written on 'PLTIN' plus one. If NFDATA = 0, NFDATA is taken as NFDATA + 1 (NFDATA is assigned for the previous plot as specified on Card No. 3, or equal to one (1) if this is the first plot of the job.

SQUARE – The size of a square in inches, is used to create a grid for selecting data points from the data file to be written on 'PLTIN'.
- Only the points within the region specified by the $PLOTAREA card (Card No. 10) are considered.
- Only one point is allowed to lie in any one square of the grid.
- If SQUARE is less than or equal to 0.0, then all points lying within the region specified by the $PLOTAREA card are selected.

ISLECT – Data skip number, *i.e.*, every ISLECT'th record of the data will be selected for plotting. The default value of ISLECT is 1. In this case, every record will be plotted.

NDFMT – If NDFMT is not equal to 0, then, a $DATAFMT card must be input (Card No. 6).

NBOUND – If NBOUND > 0, NBOUND is the number of boundary point cards to be read in.
If NBOUND < 0, |NBOUND| is the boundary file number on 'PLTBND' which will be used for plotting.
If NBOUND = 0, NPROB is the boundary file number on 'PLTBND' to be used for plotting.

NBFMT – If nonzero, then, a $BNDRYFMT card (Card No. 9) must be input.

NOLABL – The total number of plot label cards. A maximum of five cards is permitted - see Card(s) No. 7.

3.2.3 The Plot Parameter Commands

The input of the first five cards in this group (Card No. 5a, 5b, 5c, 5d and 5e) will depend on the value of 'KPLOT' as specified on card No. 4. Only one of the five cards as described below is required for each plot. The remaining cards in this group will depend on the other parameters such as NBFMT, NOLABL, *etc.*, as specified on Card No. 4. The plot region command, $PLOTAREA, is always required.

For the SAP2D program, the cartesian co-ordinate system is used. Therefore, one parameter, $POLAR, which specifies the polar co-ordinates will not be discussed here.

(a) If KPLOT = DD, then input the following card; otherwise proceed to (b).

Card No. 5a:
FORMAT (2I5)

READ , NPROBI, NPROB

NPROBI – Reference subproblem number (NPROBI must be less than NPROB). If NPROBI > 0, then nodal point displacements of subproblem NPROBI are subtracted from corresponding nodal point displacements of subproblem NPROB.
If NPROBI = 0, then displacements of subproblem NPROB are used alone.

NPROB – Displacements of subproblem number NPROB will be plotted (relative to subproblem NPROBI).

Skip to (f) – Card No. 6.

(b) If KPLOT = ST, then input the following card; otherwise proceed to (c).

Card No. 5b:
FORMAT (I5)

READ , NPROB

NPROB — Subproblem number, *i.e.*, stress trajectories of subproblem NPROB will be plotted.

Skip to (f) – Card No. 6.

(c) If KPLOT = MJ or MN, then input the following card; otherwise proceed to (d).

Card No. 5c:
FORMAT (4I5)

READ ,NPROB, LCONTR, NCONTR, LRANGE

NPROB – Subproblem number, *i.e.*, major or minor principal stresses of subproblem NPROB will be plotted.

LCONTR – If nonzero, then a $CONTOURS card (Card No. 12) is required.

NCONTR – If NCONTR > 0, then NCONTR is the number of $CONTOUR cards to be input (Card No. 13).

LRANGE – If nonzero, then a $RANGE card (Card No. 14) is required.

Skip to (f) – Card No. 6.

(d) If KPLOT = SF, then input the following cards; otherwise proceed to (e).

Card No. 5d:
FORMAT (6I5)

READ , NPROB, NSF, NUMMAT, LCONTR, NCONTR, LRANGE

NPROB – Subproblem number, *i.e.*, yield factor or local factor of safety for subproblem NPROB is to be plotted.

NSF – A flag selects the type of yield factor or local factor of safety. The calculation of yield factor is either based on the Mohr-Coulomb or the Drucker-Prager yield criteria (See Appendix C for more details).
NSF = 1, Mohr-Coulomb criterion;
NSF = 2, shear stress approach; and
NSF = 3, Drucker-Prager yield criterion.

NUMMAT – Number of material types.
NUMMAT card(s) follows immediately after this card.
The maximum material number is 10.
Note: When specify the material number, it must be consistent with the number as specified in the SAP2D input if the file SAPOUT is to be used.

LCONTR – If nonzero, then input a $CONTOURS card (Card No. 12).

Card No. 5d (continued)

NCONTR – If NCONTR > 0, a total of 'NCONTR' $CONTOUR cards need to be input (Card No. 13).
Note: A point contours plot demands the $CONTOURS card (Card No. 12), or at least one $CONTOUR card (Card No. 13). A combination of both can be used.

LRANGE – If nonzero, then input a $RANGE card (Card No. 14).

A total of 'NUMMAT' material cards must follow immediately:

Card No. 5d-1:
FORMAT (2F10.2)

READ ,COHESC, PHI

COHESC – The cohesive strength of material (same unit as that of stress).
PHI – The angle of internal friction in degrees.

Skip to (f) – Card No. 6.

(e) If KPLOT = SC or NC, then input the following card; otherwise proceed to (f).

Card No. 5e:
FORMAT (4I5)

READ , NPROB, LCONTR, NCONTR, LRANGE

NPROB – Subproblem number, *e.g.*, the shear stress or normal stress acting on a specified plane for subproblem NPROB will be plotted.
LCONTR – Same as described in Section 3.2.3(d).
NCONTR – Same as described in Section 3.2.3(d).
LRANGE – Same as described in Section 3.2.3(d).

(f) If NDFMT specified on Card No. 4 is greater than zero, then this $DATAFMT card (Card No. 6) is required. Otherwise, proceed to (g).

Card No. 6:
FORMAT (A10, 17A4, A2)

READ , Label, (NDFORM(I), I = 1, 18)

Label	–	$DATAFMT
NDFORM	–	Format for reading records from the data file. The default format is (1X, 5E15.7). Note: The parentheses must be included.

(g) If NOLABL specified on Card No. 4 is greater than zero, then a total of NOLABL title cards (Card No. 7) are required. Otherwise, proceed to (h).

Card(s) No. 7:
FORMAT (20A4)

- Each card corresponds to one line of individual plot title.
- The maximum value of NOLABL is 5, *i.e.*, A maximum of five lines are permitted.

(h) If NBSET specified on Card No. 1 is zero, and NBOUND specified on Card. No. 4 is greater than zero, then, a total of NBOUND boundary point cards - Card(s) No. 8 are required. Otherwise, proceed to (i), *i.e.*, Card No. 9.

Card(s) No. 8:
FORMAT (1X, 2E15.7, I5)

READ , X, Y, IPEN

X	–	The X (horizontal) co-ordinate of a boundary point.
Y	–	The Y (vertical) co-ordinate of a boundary point.
IPEN	–	The plotter pen code: = 2, pen down (for solid line). = 3, pen up (no line). = 4, pen down but a dashed line is drawn.

(i) If NBFMT specified on Card No. 4 is not equal to zero, then, a $BNDRYFMT card (Card. No. 9) is required. Otherwise proceed to (j).

Card No. 9:

FORMAT (A10, 17A4, A2)

READ , Label, (NBFORM(I), I=1,18)

Label	–	$BNDRYFMT
NBFORM	–	The format used to read the boundary point cards. The dafault format is (1X, 2E15.7, I5). Note: The parentheses must be included.

(j) The $PLOTAREA card defining the plot region is always required.

Card No. 10:

FORMAT (A10 ,6F10.0)

READ , Label, XAXIS, YAXIS, XMIN, XMAX, YMIN, YMAX

Label	–	$PLOTAREA
XAXIS	–	The length of plotting region, in inches, in the X-direction.
YAXIS	–	The length of plotting region, in inches, in the Y-direction.
XMIN	–	The minimum X co-ordinate of the plotting region.
XMAX	–	The maximum X co-ordinate of the plotting region.
YMIN	–	The minimum Y co-ordinate of the plotting region.
YMAX	–	The maximum Y co-ordinate of the plotting region.

Note: XMIN, XMAX, YMIN and YMAX are in logical units. Only the data points that lie within the rectangular region bounded by these co-ordinates will be plotted. This is the plotting region.

The default values for XAXIS and YAXIS are device dependent.

(k) The $SCALE card is required only if KPLOT = DD or ST as specified on Card No. 4. Otherwise proceed to (l).

Card No. 11:
FORMAT (A10, F10.0)

READ , Label, SCALE

Label – $SCALE

SCALE – The scaling factor which will be used for vector or tensor plot, is the number of logical units per inch.
Note: The scale will be approximate only if the Tektronix 4663 plotter with the A3 option is specified.

(l) The $CONTOURS card is required only if a point contour plot (*i.e.*, KPLOT = MJ, MN, SF, SC, or NC) is requested, and, if the value of LCONTR specified on Card No. 5c, 5d or 5e is non-zero. Otherwise, proceed to (m).

Card No. 12:
FORMAT (A10, F10.0, I10, 2F10.0)

READ , Label, CNTINT, MMREAD, ZMIN, ZMAX

Label – $CONTOURS

CNTINT – The size of contour intervals. The maximum value of CNTINT is 35.

MMREAD – An indicator which will be used for selecting the maximum and minimum values of data for plotting. If ZMIN and/or ZMAX is not used, then the minimum and maximum values of data found on the data file will be used.
= 0, do not use either ZMIN or ZMAX.
= 1, use ZMIN only.
= 2, use ZMAX only.
= 3, use both ZMIN and ZMAX.

ZMIN – The minimum level of contours.

ZMAX – The maximum level of contours.

(m) The $CONTOUR card is required only if a point contour plot (*i.e.*, KPLOT = MJ, MN, SF, SC or NC) is requested, and, if NCONTR specified on Card No. 5c, 5d or 5e is non-zero.

Card(s) No. 13:
FORMAT (A10, 2F10.0)

READ , Label, CMIN, CMAX

Label	—	$CONTOUR
CMIN	—	The lower bound of the contour interval.
CMAX	—	The upper bound of the contour interval.

Note: This card is used to define a single contour interval. As many as twenty of these cards may be input for a plot.

(n) The $RANGE card is required only if a point contour plot (KPLOT = MJ, MN, SF, SC or NC) is requested, and, if the value of LRANGE specified on Card No. 5c, 5d or 5e is non-zero.

Card No. 14:
FORMAT (A10, 2F10.0)

READ , Label, RMIN, RMAX

Label	–	$RANGE
RMIN	–	The minimum data value to be plotted.
RMAX	–	The maximum data value to be plotted.

Note: RMIN and RMAX define a range of data values to be used in a contours plot. Only points having a Z value within this range will be plotted.

3.2.4 Block of Cards Defining the Boundaries

This block of cards is conditional. It is required only if the value of NBSET, specified on Card No. 1, is less than 0. Then, NBSET sets of card boundary data should follow. Note that the sets of boundary files are separated by an end of file mark but no end of file mark before the first set of boundary file.

Card(s) No. 15:

FORMAT (1X, 2E15.7, I5)

READ , X, Y, IPEN

X — The X (horizontal) co-ordinate of a boundary point.

Y — The Y (vertical) co-ordinate of a boundary point.

IPEN — The plotter pen code:

= 2, pen down (for solid line)

= 3, pen up (no line)

= 4, pen down but a dashed line is drawn.

4.0 FURTHER REMARKS ON BOUNDARY FILES

A boundary file is used to define the boundary of a finite element model. Beyond or outside this boundary, no data (stress or displacement *etc.*,) will be plotted. It is a sequence of any number of data records followed by an end of file mark (CTRL/Z for the VAX VMS system). Each record contains items X, Y and IPEN, in that order. The definition of X, Y and IPEN are already described. The boundary is plotted by straight line movements of the plotter pen from one boundary point to the next in the order they appear on the file. The type of line drawn between points depends on IPEN, the plotter pen code, of the point to which the pen is moving.

A boundary is not restricted to a simple geometry connected by a few straight lines. Therefore, a boundary is further defined as a set of one or more closed polygons, called loops. In the present version of the program a maximum of ten loops are allowed. On a boundary file a loop has a well-defined structure. It is an ordered set of data records such that the first and last records have the same X and Y co-ordinates. Also, the first record must have IPEN set to 3 so that no line is drawn from the previous pen position to the starting point of the loop. The order of records must be such that the data points, for which the boundary loop is being drawn, appear to the left of the direction of the plotter pen movement. In other words, if the data points which will be plotted are contained in the interior of the loop, then the boundary points defining the loop should be in the counter-clockwise direction. If the data points are to be plotted exterior to the loop, then the boundary points along a loop should be in the clockwise direction.

All the boundary files for one plot job are stored together on an auxiliary, sequential I/O device, with logical file name PLTBND.

The boundary file may be created in one of two ways. One method to create PLTBND is to run another sub-program, called BNDGEN, using SAPOUT as an input prior to running SAPPLT. The alternative is to input the data records on cards or card images within the regular input stream as described previously.

The parameter NBSET, specified on Card No.1, tells the program which method is to be used. The files are referenced in the program by numbers corresponding to their position on PLTBND; the first file is number 1, the second is number 2 and so on.

A boundary file generated and placed on PLTBND is not the only way to input a boundary for a plot. A temporary boundary file can be created and stored only for the duration of the plot. This is achieved by specifying one of the plot parameters, NBOUND, as described for Card No. 4. In this case, any number of boundary data records on cards or card images can be input, and, the boundary will be plotted in the order of input.

4.1 PROGRAM BNDGEN

Program BNDGEN generates a complete boundary file for each subproblem of a finite element model using SAPOUT (output from the SAP2D program) as an input. No other card or card image input is required.

Boundary data are then written onto the file PLTBND using format (1X, 2E15.7, I5). Boundary data consists of a set of nodal co-ordinates (X and Y co-ordinates) describing one or more closed loops, in a counterclockwise or clockwise direction, corresponding to the model perimeter. As described earlier, a maximum of 10 loops are permitted.

4.2 FILE DEFINITIONS IN BNDGEN:

There are only two files associated with the execution of the BNDGEN program, namely:

LSAP — SAP2D output file; logical file name is SAPOUT.

LBOND — Logical unit on which the generated boundary files are written in logical co-ordinates. The logical file name is PLTBND.

An example to create a boundary file using the BNDGEN on the VAX-11/750 system is given as follows:

```
$ assign sapoutdat.dat sapout
```

```
$ assign pltbnddat.dat pltbnd
$ run bndgen
```

Note: the '$' sign is a DEC prompt.

5.0 SAPPLT COMMAND PROCEDURE

The SAPPLT command and its sub-command procedures designed, for the VAX VMS operating system, are given respectively in Appendix A and B.

To run the program SAPPLT, the input files (SAP2D output file and the SAPPLT command file) and the output files (MRLPLT plot data, MRLPLT command file and SAPPLT print-output file) need to be specified through an interactive session. The command procedure checks all the files given by the user and makes sure they are properly defined. At the end of this interactive session, the sub-command procedure SAPPLTSUB.COM is called and the job is then submitted to the batch queue for execution.

To access this command procedure conveniently, the user should define the following in his login.com file:

$SAPPLT:==@[FE.COMMAND]SAPPLT

Then the SAPPLT command procedure can be executed merely by typing SAPPLT in response to the DEC '$' prompt.

The command procedure does the following:

1) The user is prompted for the name of the output file generated by SAP2D. The procedure checks that the file exists.

2) The user is prompted for the name of SAPPLT command file. The procedure checks that the file exists.

3) The user is requested for a file name to hold MRLPLT plot data.

4) The user is asked for a file name to hold MRLPLT command file.

5) The user is asked whether the log file is to be printed.

6) The user is asked whether the SAPPLT print-output file is to be put on log file.

7) SAPPLT is then submitted to batch queue for execution.

5.1 EXAMPLE OF AN INTERACTIVE SESSION

To execute SAPPLT, the user simply types "sapplt" after the '$' sign. Note that the users reponse is in lowercase while the system response is indicated by uppercase.

***** session begins *****

```
$ sapplt
YOU ARE RUNNING THE SAPPLT COMMAND PROCEDURE
  THE INPUT FILES REQUIRED ARE:
    1) SAP2D OUTPUT FILE
    2) SAPPLT COMMAND FILE
  THE OUTPUT FILES PRODUCED ARE:
    1) MRLPLT PLOT DATA FILE
    2) MRLPLT COMMAND FILE
    3) SAPPLT PRINT-OUTPUT FILE
ENTER NAME OF SAP2D OUTPUT FILE
- : mysap2dout.dat
ENTER NAME OF SAPPLT COMMAND FILE
- : mysappltcmd.dat
ENTER NAME OF MRLPLT PLOT DATA FILE
- : mymrlpltdat.dat
ENTER NAME OF MRLPLT COMMAND DATA FILE
- : mymrlpltcmd.dat
DO YOU WISH TO PRINT YOUR LOG FILE (Y/N)N ? :y
DO YOU WISH TO PLACE SAPPLT PRINT-OUTPUT
  ON LOG FILE (Y/N)N ? :n
JOB SAPPLTSUB (que SYS$BATCH, ENTRY 1638) started on SYS$BATCH
$
```

***** session ends *****

6.0 EXAMPLE INPUT AND OUTPUT

The input data, as shown in Table 1, is an example input for the program SAPPLT. One of the output files produced by SAPPLT is the MRLPLT input command file which is shown in Table 2. The MRLPLT plot data file generated by SAPPLT is too large to be

listed here, however, a partial listing is shown in Table 3. The plotting examples are given in Reference [2].

Note: The sign convention adopted for the plotting is consistent with that used in the SAP2D program, *i.e.*, tension is postive. In other words, the major principal stress is the smallest value if both major and minor principal stresses are compressive. For a tensor plot, *i.e.*, the stress trajactories, compressive stresses are distingushed by a short bar drawn perpendicular to the line segment at each end. The direction of the principal stress is measured from the horizontal axis counter-clockwise postive, to the major principal stress.

Table 1 - SAPPLT Command Input File

```
    3    1    1    1        PA3    U         2.
$IDENT     MY NAME
EXAMPLE - TWO 5X14 M ROOMS SEPARATED BY A 5X10 M PILLAR
   ST    1   0.    1    0    0    0    1    0
    1
STRESS TRAJECTORIES
$PLOTAREA          0.0        0.0        0.0       25.0       90.0      110.0
$SCALE           100.0
   DD    2   0.    1    0    0    0    1    0
    0    1
DIFFERENTIAL DISPLACEMENTS
$PLOTAREA          0.0        0.0        0.0       25.0       90.0      110.0
$SCALE           0.001
   MJ    3   0.    1    0    0    0    1    0
    1    1
MAJOR PRINCIPAL STRESSES
$PLOTAREA          0.0        0.0        0.0       25.0       90.0      110.0
$CONTOURS          1.0          0
```

Table 2 - MRLPLT Command Input File (generated by SAPPLT)

```
$DATASET       3
$DEVICE      PA3    U
$BNDRYSET      1
$IDENT     MY NAME
$TITLE         1
EXAMPLE - TWO 5X14 M ROOMS SEPARATED BY A 5X10 M PILLAR
*TENSOR
$DATA          1    1
$LABEL         1
STRESS TRAJECTORIES
$BNDRY         1    0
$PLOTAREA        0.0        0.0        0.0       25.0       90.0      110.0
$SCALE         100.0
*VECTOR
$DATA          2    1
$LABEL         1
DIFFERENTIAL DISPLACEMENTS
$BNDRY         1    0
$PLOTAREA        0.0        0.0        0.0       25.0       90.0      110.0
$SCALE         0.001
*PNTCNT
$DATA          3    1
$LABEL         1
MAJOR PRINCIPAL STRESSES
$BNDRY         1    0
$PLOTAREA        0.0        0.0        0.0       25.0       90.0      110.0
$CONTOURS        1.0          0
**
```

Table 3 - A Partial list of MRLPLT Plot Data File

0.4999999E+00	0.9140001E+02	-0.1508424E+02	-0.2671533E+02	0.8865832E+02
0.1500000E+01	0.9140002E+02	-0.1486870E+02	-0.2683127E+02	0.8609081E+02
0.2500000E+01	0.9140002E+02	-0.1443881E+02	-0.2706804E+02	0.8388941E+02
0.3500000E+01	0.9140001E+02	-0.1381420E+02	-0.2742071E+02	0.8229419E+02
0.4500000E+01	0.9140001E+02	-0.1302769E+02	-0.2785640E+02	0.8141880E+02
0.5700001E+01	0.9140002E+02	-0.1194743E+02	-0.2845297E+02	0.8138792E+02
0.7100001E+01	0.9140002E+02	-0.1067601E+02	-0.2911448E+02	0.8247839E+02
0.8500000E+01	0.9140002E+02	-0.9545519E+01	-0.2967418E+02	0.8447905E+02
0.9900001E+01	0.9140002E+02	-0.8695503E+01	-0.3006555E+02	0.8705067E+02
0.1130000E+02	0.9140001E+02	-0.8224429E+01	-0.3029441E+02	0.8991966E+02
0.1270000E+02	0.9140001E+02	-0.8175132E+01	-0.3036586E+02	-0.8710731E+02
0.1410000E+02	0.9140002E+02	-0.8543845E+01	-0.3027864E+02	-0.8420253E+02
0.1550000E+02	0.9140002E+02	-0.9280545E+01	-0.3002540E+02	-0.8154189E+02
0.1690000E+02	0.9140002E+02	-0.1028480E+02	-0.2959930E+02	-0.7935159E+02
0.1830000E+02	0.9140001E+02	-0.1142109E+02	-0.2906108E+02	-0.7788553E+02

0.2272000E+02	0.1082700E+03	-0.5929070E-04	-0.7543790E-04
0.2078666E+02	0.1082700E+03	-0.6297426E-04	-0.9195794E-04
0.1954667E+02	0.1082700E+03	-0.6509258E-04	-0.1089175E-03
0.1900000E+02	0.1082700E+03	-0.6562210E-04	-0.1187600E-03
0.1760000E+02	0.1082700E+03	-0.6346768E-04	-0.1493625E-03
0.1620000E+02	0.1082700E+03	-0.5589129E-04	-0.1809665E-03
0.1480000E+02	0.1082700E+03	-0.4493526E-04	-0.2061418E-03
0.1340000E+02	0.1082700E+03	-0.3325208E-04	-0.2220811E-03
0.1200000E+02	0.1082700E+03	-0.2186106E-04	-0.2287852E-03
0.1060000E+02	0.1082700E+03	-0.1061904E-04	-0.2264693E-03
0.9200000E+01	0.1082700E+03	0.6326136E-06	-0.2147484E-03
0.7800001E+01	0.1082700E+03	0.1089010E-04	-0.1934021E-03
0.6400000E+01	0.1082700E+03	0.1744198E-04	-0.1650211E-03
0.5000000E+01	0.1082700E+03	0.1806185E-04	-0.1371431E-03
0.4000000E+01	0.1082700E+03	0.1541344E-04	-0.1222214E-03

0.4999999E+00	0.9140001E+02	0.2671533E+02
0.1500000E+01	0.9140002E+02	0.2683127E+02
0.2500000E+01	0.9140002E+02	0.2706804E+02
0.3500000E+01	0.9140001E+02	0.2742071E+02
0.4500000E+01	0.9140001E+02	0.2785640E+02
0.5700001E+01	0.9140002E+02	0.2845297E+02
0.7100001E+01	0.9140002E+02	0.2911448E+02
0.8500000E+01	0.9140002E+02	0.2967418E+02
0.9900001E+01	0.9140002E+02	0.3006555E+02
0.1130000E+02	0.9140001E+02	0.3029441E+02
0.1270000E+02	0.9140001E+02	0.3036586E+02
0.1410000E+02	0.9140002E+02	0.3027864E+02
0.1550000E+02	0.9140002E+02	0.3002540E+02
0.1690000E+02	0.9140002E+02	0.2959930E+02
0.1830000E+02	0.9140001E+02	0.2906108E+02

7.0 REFERENCES

1. Morrison, H.D., Documentation of a Plot Program; Report MRP/MRL 75-34 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa; April, 1975.

2. Yu, Y.S., Toews N.A. and Morrison, H.D.; MRLPLT Documentation (VAX-11/750 version) - A General Purpose Plotting Program for 2-D Finite Element Analysis; Division Report MRP/MRL 85-87(TR); Mining Research Laboratories, CANMET; Energy, Mines and Resources Canada, Ottawa; April 1985.

3. Toew, N.A., and Yu, Y.S., SAP2D Documentation - 2D Linear Elastic Finite Element Computer System; Report 74/138; Mining Research Laboratories, CANMET, Energy Mines and Resources Canada, Ottawa; December, 1974.

4. Toews, N.A., Yu, Y.S., and Wong, A.. S., SAP2D Documentation (VAX-11/750 version) A 2-D Linear Elastic Finite Element Computer System; Division Report MRP/MRL 85-35 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa; August, 1985.

Appendix A

SAPPLT Command Procedure

```
$ ! SAPPLT COMMAND PROCEDURE
$ !
$ WRITE SYS$OUTPUT "YOU ARE RUNNING THE SAPPLT COMMAND PROCEDURE"
$ !
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "THE INPUT FILES REQUIRED ARE:"
$ WRITE SYS$OUTPUT "    1) SAP2D OUTPUT FILE"
$ WRITE SYS$OUTPUT "    2) SAPPLT COMMAND FILE"
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "THE OUTPUT FILES PRODUCED ARE:"
$ WRITE SYS$OUTPUT "    1) MRLPLT PLOT DATA FILE"
$ WRITE SYS$OUTPUT "    2) MRLPLT COMMAND FILE"
$ WRITE SYS$OUTPUT "    3) SAPPLT PRINT-OUTPUT"
$ WRITE SYS$OUTPUT " "
$ !
$AGAIN1:
$ WRITE SYS$OUTPUT "ENTER  NAME OF SAP2D OUTPUT FILE"
$ INQUIRE SAPOUT " -- "
$ SAPOUT = F$PARSE(SAPOUT,,,,"SYNTAX_ONLY")
$ IF SAPOUT.NES."" THEN GOTO AGAIN2
$ WRITE SYS$OUTPUT "BAD FILE NAME"
$ GOTO AGAIN1
$ !
$AGAIN2:
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "ENTER  NAME OF SAPPLT COMMAND FILE"
$ INQUIRE SAPPLTIN " -- "
$ SAPPLTIN = F$SEARCH(SAPPLTIN)
$ IF SAPPLTIN.NES."" THEN GOTO AGAIN3
$ WRITE SYS$OUTPUT "SPECIFIED FILE DOES NOT EXIST"
$ GOTO AGAIN2
$ !
$AGAIN3:
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "ENTER NAME OF MRLPLT PLOT DATA FILE"
$ INQUIRE MRLPLTIN " -- "
$ MRLPLTIN = F$PARSE(MRLPLTIN)
$ IF MRLPLTIN.NES."" THEN GOTO AGAIN4
$ WRITE SYS$OUTPUT "BAD FILE NAME"
$ GOTO AGAIN3
$ !
$AGAIN4:
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "ENTER NAME OF MRLPLT COMMAND FILE"
$ INQUIRE MRLPLTCMD " -- "
$ MRLPLTCMD = F$PARSE(MRLPLTCMD)
$ IF MRLPLTCMD.NES."" THEN GOTO AGAIN5
$ WRITE SYS$OUTPUT "BAD FILE NAME"
$ GOTO AGAIN4
$ !
```

- SAPPLT command procedure continued -

```
$ AGAIN5:
$ WRITE SYS$OUTPUT " "
$ INQUIRE LOG "DO YOU WISH TO PRINT YOUR LOG FILE (Y/N)N ? "
$ WRITE SYS$OUTPUT "DO YOU WISH TO PLACE SAPPLT PRINT-OUTPUT "
$ INQUIRE PRINT "     ON LOG FILE (Y/N)N ? "
$ PRINTF := "NL:"
$ IF PRINT.EQS."Y" THEN PRINTF := "SYS$OUTPUT"
$ LOGNAM = F$EXTRACT(0,F$LOCATE(";",SAPPLTIN)-3,SAPPLTIN)
$ !
$ OPEN/WRITE FILEBLK SAPPLTFIL.DUM
$ WRITE FILEBLK SAPOUT
$ WRITE FILEBLK SAPPLTIN
$ WRITE FILEBLK MRLPLTIN
$ WRITE FILEBLK MRLPLTCMD
$ WRITE FILEBLK PRINTF
$ CLOSE FILEBLK
$ FILEDUM = F$SEARCH("SAPPLTFIL.DUM")
$ !
$ IF LOG.EQS."Y" THEN GOTO AGAIN6
$ SUBMIT/PARAMETERS='FILEDUM'-
 /LOG_FILE='LOGNAM'LOG    DISK$USER:[FE.COMMAND]SAPPLTSUB.COM
$ EXIT
$ !
$AGAIN6:
$ SUBMIT/PARAMETERS='FILEDUM'-
 /LOG_FILE='LOGNAM'LOG/NOPRINT    DISK$USER:[FE.COMMAND]SAPPLTSUB.COM
```

Appendix B

SAPPLT Sub-command Procedure

```
$ ! COMMAND PROCEDURE SAPPLTSUB.COM
$ !
$ !
$ ON ERROR THEN GOTO FINISH
$ !
$ OPEN/READ FILEBLK 'P1'
$ READ FILEBLK SAPOUT
$ ASSIGN 'SAPOUT' SAPOUT
$ READ FILEBLK SAPPLTIN
$ ASSIGN 'SAPPLTIN' FOR005
$ READ FILEBLK PLTIN
$ ASSIGN 'PLTIN' PLTIN
$ READ FILEBLK PLTCMD
$ ASSIGN 'PLTCMD' PLTCMD
$ READ FILEBLK MRLPLTCMD
$ ASSIGN 'MRLPLTCMD' FOR006
$ !
$ RUN DISK$USER:[FE.EXECUTE]SAPPLT
$ !
$FINISH:
$ CLOSE FILEBLK
$ DELETE 'P1'
```

Appendix C

Local Factor of Safety Calculations

To evaluate the stability of a structure, using the stresses obtained from a finite element analysis, the Mohr-Coulomb failure criterion and Drucker-Prager yield criterion are incorporated into the SAPPLT program.

(1) Mohr-Coulomb Criterion:

The normal stress, σ_n, and the shear stress, τ_n, acting on a plane, are defined as:

$$\sigma_n = \left(\frac{\sigma_{max} + \sigma_{min}}{2}\right) + \left(\frac{\sigma_{max} - \sigma_{min}}{2}\right) \cos 2\theta$$

and

$$\tau_n = -\left(\frac{\sigma_{max} - \sigma_{min}}{2}\right) \sin 2\theta$$

where σ_{max} and σ_{min} are the major and minor principal stresses. Note that the sign convention of tension positive is adopted throughtout.

Based on the Mohr-Coulomb criterion, shear failure occurs when:

$$|\tau_n| \geq C - \sigma_n \tan\phi$$

Where C is the cohesion and ϕ is the angle of internal friction.

(a) Safety Factor Calculation # 1, *i.e.*, NSF = 1

Referring to Figure C1, at failure we have:

$$\sin\phi = \left(\frac{\sigma_{max} - \sigma_{min}}{2}\right) / \left(\sigma_C - \frac{\sigma_{max} + \sigma_{min}}{2}\right)$$

This reduces to:

$$\frac{\sigma_C - \sigma_{min}}{\sigma_C + \sigma_{max}} = \frac{1 + \sin\phi}{1 - \sin\phi} = \tan^2\left(\frac{\pi}{4} + \frac{\phi}{2}\right)$$

Failure occurs when:

$$\sigma_C - \sigma_{min} \geq \left(\frac{1 + \sin\phi}{1 - \sin\phi}\right)(\sigma_C - \sigma_{max})$$

or:

$$\left(\frac{1 + \sin\phi}{1 - \sin\phi}\right)\left(\frac{\sigma_C - \sigma_{max}}{\sigma_C - \sigma_{min}}\right) \leq 1$$

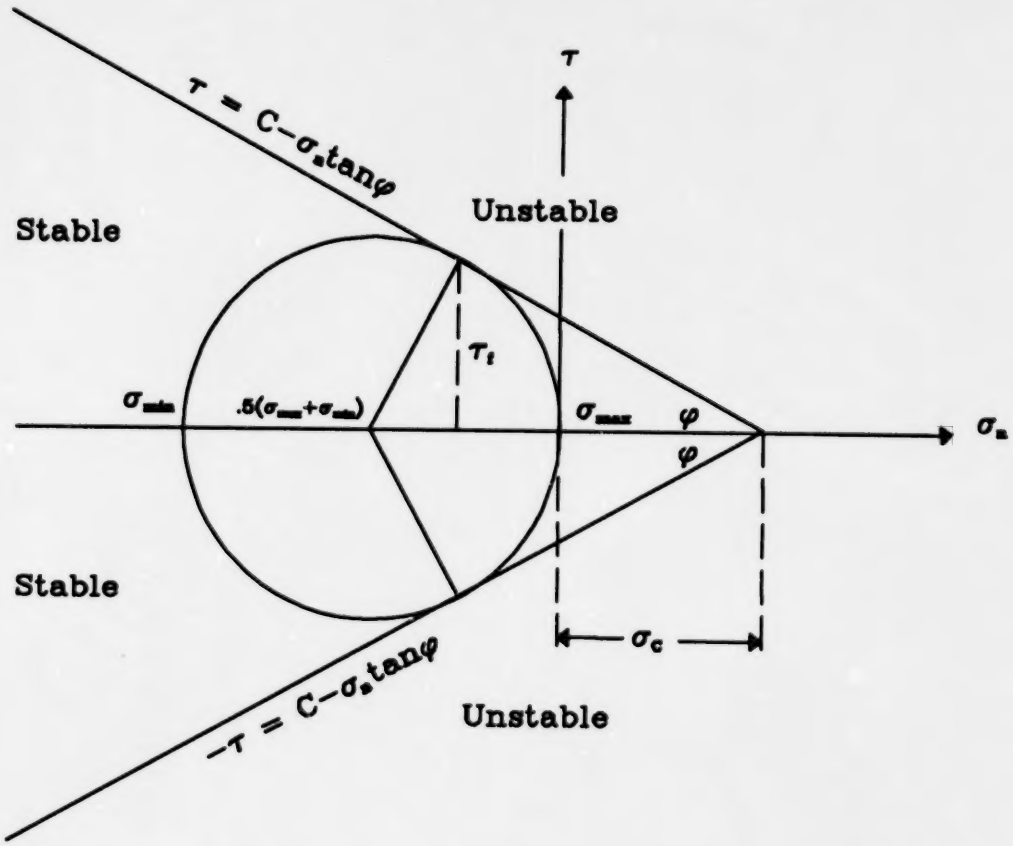

Figure C1. Mohr Diagram.

We take the left side as a definition of the safety factor, then we have:

$$\mathbf{SF} = \left(\frac{1+\sin\phi}{1-\sin\phi}\right)\left(\frac{\sigma_C - \sigma_{max}}{\sigma_C - \sigma_{min}}\right) \qquad (Eq\ A1)$$

$$\text{where} \quad \sigma_C = \frac{C}{\tan\phi}$$

This has the advantage that it is bounded by $\left(\frac{1+\sin\phi}{1-\sin\phi}\right)$

Actually, to take tension failure into account, we assume tension failure occurs

if $\sigma_{max} \geq$ MIN(0.5C, σ_C) . In this case, SF is set to -1.

If this is not the case, then, SF is calculated from Equation A1.
NOTE: SF values are truncated to 10 if SF values are $\geq$ 10; and they are truncated to 0 if SF values are $\leq$ 0.

(b) Safety Factor Calculation # 2, *i.e.*, NSF = 2

Assuming $\left(\frac{\sigma_{max}+\sigma_{min}}{2}\right)$ is fixed, the shear on the failure plane is:

$$|\tau_f| = \left(\sigma_C - \frac{\sigma_{max}+\sigma_{min}}{2}\right)\sin\phi\cos\phi$$

Now, the actual shear on the failure plane is:

$$|\tau_{(\frac{\pi}{4}+\frac{\phi}{2})}| = \left(\frac{\sigma_{max}-\sigma_{min}}{2}\right)\sin\left(\frac{\pi}{2}+\phi\right)$$

The factor of safety is defined as:

$$\mathbf{SF} = \left|\frac{\tau_f}{\tau_{(\frac{\pi}{4}+\frac{\phi}{2})}}\right| = \left(\sigma_C - \frac{\sigma_{max}+\sigma_{min}}{2}\right)\sin\phi \Big/ \left(\frac{\sigma_{max}-\sigma_{min}}{2}\right) \qquad (Eq.A2)$$

If $\sigma_{max} \geq$ MIN(0.5C, σ_C), then, tension failure is assumed to occur and SF is set equal to -1. Otherwise, SF is calculated from Eq.A2. Similarly, SF values greater than 10, are truncated to 10; and negative values are truncated to 0.

(2) Drucker-Prager Yield Criterion:

The Drucker-Prager Yield Criterion may be written as:

$$F = \left(\frac{6\sin\phi}{3-\sin\phi}\right)\sigma_m + \sqrt{3}\sqrt{J_2} - \left(\frac{6C\cos\phi}{3-\sin\phi}\right) = 0$$

Where σ_m is the mean stress and

$$\sigma_m = \frac{1}{3}\sigma_{ii} = \left(\frac{\sigma_{xx}+\sigma_{yy}+\sigma_{zz}}{3}\right)$$

and J_2 is the second invariant of the deviatoric stress tensor.

$$J_2 = \frac{1}{2}S_{ij}\,S_{ij}$$

$$S_{ij} = \sigma_{ij} - \delta_{ij}\sigma_m$$

$$J_2 = \frac{1}{2}\{(\sigma_{xx}-\sigma_m)^2 + (\sigma_{yy}-\sigma_m)^2 + (\sigma_{zz}-\sigma_m)^2\} + (\tau_{xy})^2 + (\tau_{xz})^2 + (\tau_{yz})^2$$

(c) Safety Factor Calculation # 3, *i.e.*, NSF = 3

Referring to Figure C2:

$$\sqrt{J_{2f}} = \frac{1}{\sqrt{3}}\left(\frac{6C\cos\phi}{3-\sin\phi}\right) - \left(\frac{6\sin\phi}{\sqrt{3}(3-\sin\phi)}\right)\sigma_m$$

The factor of safety is defined as:

$$SF = \frac{\sqrt{J_{2f}}}{\sqrt{J_2}} \qquad (Eq.A3)$$

To avoid large numbers, the factor of safety is defined as SF = AMIN1 (10.0, SF). Also, to avoid negative numbers, the factor of safety is redefined as: SF = AMAX1 (0.0, SF)

In case either of the principal stresses > 0.5C, a tension failure is assumed, and, SF is set equal to -1.

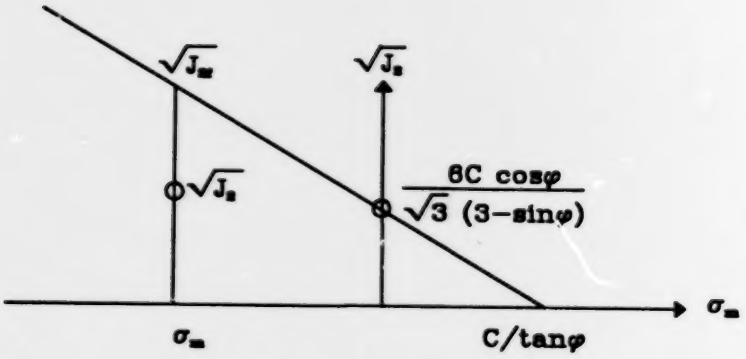

Figure C2. σ_m vs $\sqrt{J_2}$ Diagram.